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Implementation of the Project-Based Learning (PjBL) Model to Improve Students' Conceptual Understanding

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Abstract:
This study aims to analyze the effectiveness of the implementation of the Project-Based Learning (PjBL) model in improving students' conceptual understanding of the topic of states of matter and their changes. This study employed a quantitative approach with a pre-experimental method and a one-group pretest-posttest design. The research subjects consisted of 9 students of the Primary School Teacher Education (PGSD) Study Program. The research instrument was a conceptual understanding test administered before and after the implementation of the PjBL model. The learning process was implemented through an ice cream making project as a learning context for identifying and explaining the concept of changes in the states of matter in everyday life. The research data were analyzed using descriptive statistics, normalized N-Gain scores, and a paired samples t-test. The results show an improvement in students' conceptual understanding after the implementation of the PjBL model, as indicated by an increase in the mean score from 60,00 in the pretest to 77,22 in the posttest. The mean N-Gain value of 0,43 falls into the medium category. The results of the paired samples t-test indicate a significant difference between the pretest and posttest scores. These findings indicate that the implementation of the PjBL model plays a significant role in improving students' conceptual understanding of the topic of states of matter and their changes. Project-based learning provides contextual learning experiences through students' involvement in designing and carrying out projects, so that the concept of changes in the states of matter can be understood more concretely and meaningfully. The results of this study may serve as an alternative for implementing innovative instruction in science learning, particularly in developing conceptual understanding through project-based learning experiences.

Introduction (مقدمة)

Physics is a branch of natural science that studies the properties, structure, and changes of matter as well as energy, which are closely related to everyday life (Harefa, 2019). Physics is a fundamental science for human life because of natural phenomena that can be directly observed, such as falling objects, boiling water, and melting ice. One of the physics topics closely related to daily life is the states of matter and their changes. The discussion of states of matter and their changes covers the states of matter as well as changes of state such as fusion, freezing, evaporation, melting, sublimation, condensation, and crystallization (Serway & Jewett, 2018).

The topic of states of matter and their changes is also taught in elementary school as part of the Natural and Social Sciences (IPAS) subject. Accordingly, prospective elementary school teacher students are also required to have an adequate understanding in order to deliver this material to their pupils. In practice, a considerable number of pupils still experience conceptual misunderstandings in learning (Qatrunnada dkk, 2025; Damayanti dkk, 2025). Similarly, students still hold conceptual misconceptions concerning the topic of states of matter and their changes, particularly in distinguishing physical changes from chemical changes and in understanding the concept of energy involved in each process of change of state (Siparno, 2013).

The problem of students' low conceptual understanding of physics content cannot be separated from the instructional approach that is applied. Lecturer-centered instruction using the lecture method is still less effective for building deep conceptual understanding (Freeman et al., 2014; Prince, 2004). The lecture method tends to place students as passive recipients of information, without providing room for them to construct knowledge independently. Instruction that gives students space to be actively involved in the learning process, to interact with their environment, and to relate new concepts to their prior knowledge can build meaningful conceptual understanding (Slavin, 2018).

One effort that can be made to address this problem in order to encourage student activeness, improve conceptual understanding, and develop skills in designing innovative instruction is the Project Based Learning (PjBL) approach (Chen & Yang, 2021; Guo et al., 2022; Setiawan et al., 2022; Rahmawati et al., 2024; Hidayah et al., 2026). PjBL is a form of instruction that places students as active subjects in completing real projects related to the concepts being studied (Kokotsaki et al., 2021; Zhang & Ma, 2023). Through PjBL, students are encouraged to think critically, collaborate, communicate, and produce products of practical value (Almulla, 2022; Fitri et al., 2023; Indriyani et al., 2023).

Although empirical evidence regarding the effectiveness of PjBL on science conceptual understanding is quite abundant, a number of research gaps remain unaddressed. First, a recent systematic review of the PjBL-STEM literature (2019–2024) still identifies clear gaps in understanding the practical implementation and effectiveness of this integrated methodology across diverse educational contexts. Second, a systematic review of PjBL design and implementation conducted over a sustained period (2015–2024) shows that the majority of PjBL research remains concentrated at the secondary and higher education levels, while research at the primary and early childhood education levels remains relatively limited—a gap directly relevant to the context of pre-service elementary school teacher education (PGSD) examined in this study. Third, a recent review of STEM-based PjBL aimed at improving conceptual understanding among pre-service teachers still identifies gaps in longitudinal evaluation, AI-based adaptive learning personalization, and the absence of standardized instruments for consistently measuring conceptual change. In other words, research on PjBL among PGSD students that specifically and quantitatively measures changes in conceptual understanding on the topic of states of matter and their changes (for example, through a pretest-posttest design with N-Gain analysis) remains scarce, particularly when combined with contextual projects closely related to students' everyday experiences.

The ice cream making project was selected as a learning medium because it directly involves the phenomenon of the change of state of matter from liquid to solid, which constitutes the core of the learning material (Putri et al., 2024; Ariani et al., 2025). In addition, ice cream is a product close to students' everyday lives, so that the learning becomes more contextual and engaging (Iskandar & Okimustava, 2024; Putri et al., 2025). Its production process also integrates various science concepts such as heat transfer, freezing point, and the effect of dissolved substances, thereby providing a comprehensive learning experience (Wardani et al., 2023; Maulida et al., 2025).

The ice cream making activity within PjBL was designed through several systematic stages that reflect the scientific process. Students began with the project planning stage, then conducted the ice cream making experiment with varied treatments, observed and recorded the changes that occurred, and analyzed the data from their observations, up to presenting their findings and the resulting product. This series of activities not only improves conceptual understanding but also develops science process skills that students can later implement when teaching in elementary school.

Based on the description above, there is a strong urgency to conduct research that examines in depth the implementation of PjBL in an effort to improve PGSD students' understanding of states of matter and their changes. A strong command of the physics content on this topic will equip prospective elementary school teachers with the professional competence required to deliver science material effectively, contextually, and enjoyably to pupils in elementary school. Accordingly, this study is expected to make a tangible contribution to the development of the quality of teacher education, while also enriching research on instructional innovation in PGSD study programs in Indonesia.

Method (منهج)

This study applied a quantitative approach with a quasi-experimental design of the One Group Pretest-Posttest type, which involved a single group with measurements before and after the treatment (Bell, 2016; Han et al., 2016). The research design is expressed as $O_1 \rightarrow X \rightarrow O_2$, where O_1 denotes the pretest, X is the treatment in the form of the implementation of the Project Based Learning (PjBL) model, and O_2 is the posttest.

The research population consisted of 9 students of the PGSD Study Program. The sampling technique was purposive sampling, taking into consideration that the subjects had never previously received project-based instruction (Condliffe, 2017). The independent variable in this study was the implementation of the PjBL model, while the dependent variable was students' understanding of states of matter and their changes, which covers the ability to comprehend concepts, to explain, and to analyze scientific phenomena (Kurniawan & Wibowo, 2020).

The implementation of PjBL referred to the main stages of project-based learning, namely determining the essential question, planning the project, arranging the schedule, monitoring the implementation, assessing the outcomes, and evaluating the learning experience (Condliffe, 2017; Bell, 2016). The project activity carried out was ice cream making as a simple experiment to examine changes in the states of matter contextually.

The research instruments consisted of a five-item essay test and an observation sheet on the implementation of the learning process. Instrument validity was tested using Pearson correlation, while reliability was measured with Cronbach's Alpha, which indicated a high level of internal consistency of the instrument (Ghozali, 2016; Widodo & Kadarwati, 2019).

Data analysis was carried out through descriptive and inferential statistics. The improvement in understanding was calculated using the normalized gain (N-Gain) value in order to examine the effectiveness of the instruction (Fitri et al., 2018). Subsequently, hypothesis testing was conducted using a paired samples t-test at a significance level of 0,05, after the prerequisite normality test using Shapiro-Wilk had been fulfilled (Razali & Wah, 2016).

Result (نتائج)

Based on the pretest and posttest data, the following descriptive statistics were obtained:

Table 1. Descriptive Statistics of Pretest and Posttest Scores

Data	N	Mean	SD	MIN	MAX
Pretest	9	60,0	9,35	40	75
Posttest	9	77,2	9,01	55	85

Based on Table 1, the mean pretest score of 60,0 increased to 77,2 in the posttest. This indicates an improvement in students' understanding after the implementation of the Project Based Learning (PjBL) model. The results of the N-Gain calculation are presented in Table 2 below

Table 2. N-Gain Results

Mean Pretest	Mean Post Test	N Gain	Category
60,0	**77,2**	**0,43**	**Medium**

The N-Gain value of 0,43 falls into the medium category, which indicates that the implementation of PjBL was sufficiently effective in improving students' conceptual understanding.

Discussion (مناقشة)

The research results show that the implementation of Project Based Learning (PjBL) produced a significant improvement in students' conceptual understanding, as indicated by the increase in mean scores and by the significant statistical test results. However, when analyzed more deeply, the improvement, which falls into the medium category (N-Gain = 0,43), indicates that the effectiveness of PjBL is not absolute but rather contextual and influenced by various instructional factors.

The moderate N-Gain findings in this study are consistent with patterns widely reported in other PjBL research within science and natural science education contexts. For example, Arifah and Wulandari's (2026) study on the implementation of PjBL for ecosystem material found a control class N-Gain of 0.45 (moderate category), a value nearly equivalent to the findings of this study, while the experimental class supported by additional media achieved the high category. This indicates that improvements in conceptual understanding through PjBL tend to fall within the moderate range when not combined with additional supporting media or treatments. The consistency of such findings is further reinforced by a global-scale systematic review of PBL, which concluded that although PjBL generally has a positive impact on academic achievement, the quality and consistency of evidence for its effectiveness—particularly at the primary education level and in pre-service elementary teacher preparation—remains limited and varies across studies. Thus, the moderate category result in this study is not an anomaly, but rather a reflection of the general tendency that PjBL requires additional reinforcement (such as media, duration, or more intensive reflective mentoring) to achieve a high improvement category, as will be discussed further in the limitations section.

Theoretically, PjBL is rooted in constructivism, which emphasizes that knowledge is actively constructed through direct experience (Bell, 2016). In the context of this study, the ice cream making project activity functioned as experiential learning that enabled students to connect an abstract concept (changes in the states of matter) with a real phenomenon. This finding is in line with Han et al. (2016), who showed that PjBL significantly improves conceptual understanding because it involves the integration of conceptual and procedural knowledge.

More specifically, the ice cream-making project supports conceptual understanding of changes in the states of matter because students do not merely observe the phenomenon of freezing, but directly experience and manipulate the variables that cause it. When salt is sprinkled onto the ice surrounding the ice cream mixture container, a depression in the freezing point of the ice-salt mixture occurs through the mechanism of colligative properties of solutions, causing the mixture's temperature to drop well below 0°C and triggering the freezing of the milk mixture within it (Iskandar & Okimustava, 2025). This process simultaneously involves an endothermic reaction during the dissolution of salt in ice, which accelerates heat absorption from the mixture, allowing students to directly observe the relationship between heat transfer and the change of liquid substance into solid form. By continuously stirring the mixture during the freezing process, students can also observe how the size of the ice crystals formed affects the final texture of the product—a phenomenon that connects the microscopic concept (crystal formation) with the macroscopic experience (the smooth texture of ice cream). This sequence of experiences bridges the macroscopic, submicroscopic, and symbolic levels of understanding that have long been a weak point in pre-service elementary school teachers' conceptual understanding of states of matter (Sopandi et al., 2017). In other words, the ice cream project serves not only as an affectively engaging context, but also provides a "living laboratory" that enables students to empirically verify concepts previously understood only textually, such as the effect of dissolved substances on freezing point and the crystallization process.

Furthermore, the improvement in conceptual understanding can be explained through higher-order cognitive engagement (higher-order thinking skills). PjBL requires students not only to remember or understand (C1–C2), but also to analyze and evaluate (C4–C5) during the process of planning and carrying out the project. This is supported by the study of Widodo and Kadarwati (2019), which states that PjBL is effective in fostering higher-order thinking abilities through investigative and reflective activities.

Nevertheless, the improvement achieved, which remained only in the medium category, indicates the presence of limitations in the implementation. One factor that may have exerted an influence is the relatively short duration of the intervention. The study by Condliffe (2017) affirms that the effectiveness of PjBL depends greatly on adequate implementation time, because the process of knowledge construction requires repeated cycles of exploration, reflection, and revision. In addition, the small sample size (N=9) also has the potential to limit the generalizability of the research results.

From a methodological perspective, the use of a One Group Pretest-Posttest design without a control group also constitutes a limitation that needs to be taken into account. This design is susceptible to threats to internal validity such as the testing effect and maturation (Creswell, 2014). Therefore, although the results indicate an improvement, not all of it can be attributed exclusively to the PjBL intervention.

On the other hand, the results of this study remain consistent with various recent empirical studies showing that PjBL is effective in improving science learning outcomes. For instance, Kurniawan and Wibowo (2020) found that PjBL significantly improved conceptual understanding in science, while the study by Fitri et al. (2018) showed that a project-based approach was able to increase student engagement and learning outcomes simultaneously. Globally, this trend is also supported by the OECD (2018) report, which emphasizes the importance of project-based learning in developing twenty-first century competencies.

Thus, it can be concluded that PjBL is an effective approach for improving conceptual understanding, particularly when it is supported by a well-designed instructional plan, sufficient duration, and the integration of reflective activities. In order to enhance its effectiveness, further research is recommended to employ a stronger experimental design (for example, a true experimental design) and to involve a larger sample so that the results obtained are more generalizable.

Conclusion (خاتمة)

The implementation of Project-Based Learning (PjBL) through an ice cream-making project demonstrated an improvement in students' conceptual understanding of states of matter and their changes, indicated by an increase in the mean score from 60.00 (pretest) to 77.22 (posttest), with an N-Gain of 0.43 (moderate category). The ice cream-making project helped bridge conceptual understanding across the macroscopic, submicroscopic, and symbolic levels through direct experience with the phenomena of freezing point depression and changes in the state of matter. Given that this study employed a one-group pretest-posttest design without a control group and a small sample size (N=9), these findings are preliminary and cannot yet be generalized to the broader population of PGSD students. The observed improvement may also have been influenced by factors outside the intervention, such as testing effects and maturation, meaning the specific magnitude of PjBL's contribution cannot yet be determined with certainty.

Future research is recommended to employ an experimental design with a control group and a larger sample size to strengthen the validity of the findings, as well as to explore mediating variables (such as intervention duration and the intensity of reflective activities) that influence the magnitude of improvement in conceptual understanding through PjBL.

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